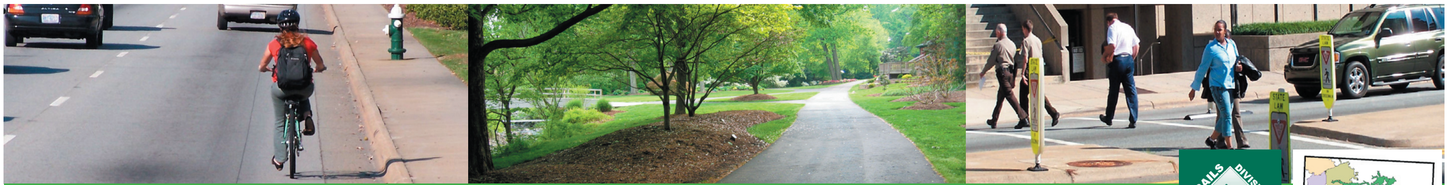


Appendix E: Bicycle Level of Service Model Description

E.1 Bicycle Level of Service Data Collection and Inventory Guidelines

INSTRUCTIONS FOR FIELD DATA COLLECTORS

Safety Instructions - IMPORTANT

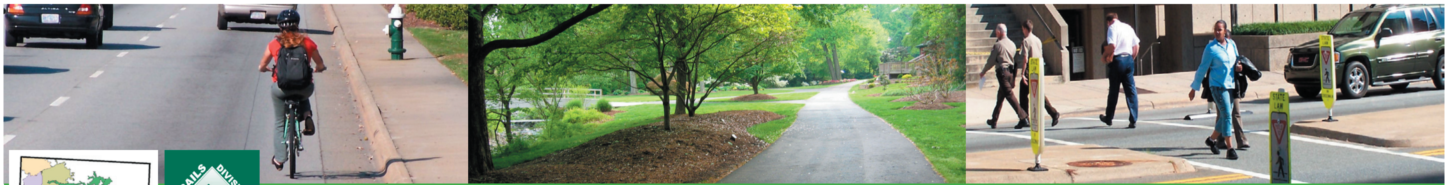
- **ALL DATA COLLECTORS WHO ARE WORKING IN THE STREET ENVIRONMENT SHALL WEAR SAFETY VESTS**. There are no exceptions to this rule.
- All data collectors should use utmost caution in crossing streets and driveways, and shall follow traffic laws at all times.
- All data collectors should maintain a constant awareness of surrounding traffic conditions and should ensure that data collection activities do not interfere with their attention to safety within the roadway environment. If you feel at any point that your safety is compromised, you should immediately **STOP** collection data and move to a safer location.

Bicycle Level of Service Model Data Needs

The following data items are used to compute the final Bicycle Level of Service (BLOS) score for each roadway segment. Please use the following guidelines when gathering available roadway data and making measurements and observations in the field.

Existing Data (from maps and electronic databases)

<u>Annual Average Daily Traffic (AADT)</u> – Enter this



information into the database for each roadway segment from existing traffic count databases. If necessary, use assumed values based on surrounding land uses or taking 15 minute counts in the field. AADT is converted by the database to hourly traffic volume by lane in one direction of travel.

Percent Heavy Vehicles (% HV) – Enter this information into the database from existing traffic composition databases. Generally, a heavy vehicle is any large truck with six or more tires. If necessary, use assumed values based on surrounding land uses or taking 15 minute counts in the field.

Field Data (from data collection measurements)

Number of lanes of traffic (L) - Record the total number of *through* traffic lanes, in both directions, of the road segment. The presence of continuous right-turn lanes should be noted in the comments field (they should not be counted as through lanes).

Configuration (Cnfg.) – Record the configuration of the road segment as D = Divided (has a median), U = Undivided, OW = One-Way, or S = Center Turning Lane. The programmed database will output the number of travel lanes in each direction. **Note in the comments if there are a different number of through lanes in the opposing directions.**

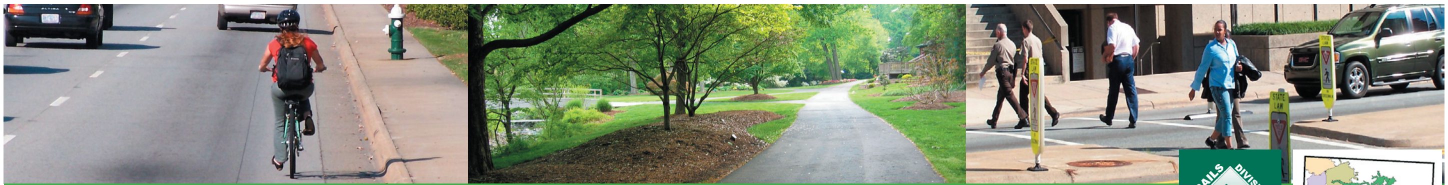
Posted Speed Limit (SP_p) - Record as posted in m.p.h. The database is programmed to add approximately 9 m.p.h. (15 k.p.h) to the posted speed to reflect the typical 85th percentile speed (unless 85th percentile speeds are available from existing sources).

Width of pavement for the outside lane and shoulder (W_t) – This measurement is taken from the center of the road (yellow stripe) to the gutter pan of the curb (or to the curb if there is no gutter present). In the case of a multilane configuration, it is measured from the outside lane stripe to the edge of pavement. **W_t does not include the gutter pan.** When there is angled parking adjacent to the outside lane, W_t is measured to the traffic-side end of the parking stall stripes. **The presence of unstriped on-street parking does not change the measurement; the measurement should still be taken from the center of the road to the gutter pan.**

Width of paving between the shoulder/edge stripe and the edge of pavement (W_l) – This measurement is taken when there is additional pavement to the right of an edge stripe, such as when striped shoulders, bike lanes, or parking lanes are present. It is measured from the shoulder/edge stripe to the edge of pavement, or to the gutter pan of the curb. **W_l does not include the gutter pan.** When there is angled parking adjacent to the outside lane, W_l is measured to the traffic-side end of the parking stall stripes.

Width of pavement striped for on-street parking (W_{ps}) – **Record this measurement only if there is parking to the right of a striped bike lane.** If there is parking on two sides on a one-way, single-lane street, the combined width of striped parking is reported. W_{ps} does not include the gutter pan.

Total Roadway Width (TRW) – This measurement



is taken from one shoulder or curb face to the other shoulder or curb face. **This measurement DOES include the gutter pan.** If the roadway is divided, the width of the grass/concrete median should be included in the measurement and the width of the median itself should be listed in the comments field.

Pavement Condition:

Travel Lane (PC_t) - Pavement condition of the outside motor vehicle travel lane is evaluated according to FHWA's five-point pavement surface condition rating shown below. Unpaved travel lanes should be scored with a zero (0).

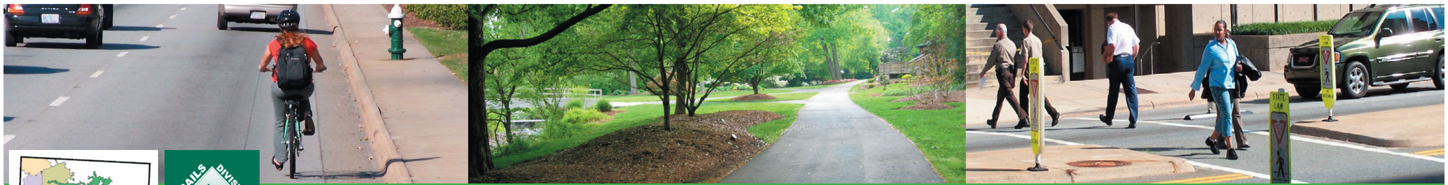
Shoulder or Bike lane (PC_l) - Pavement condition of the shoulder or bike lane is evaluated according to the FHWA's five-point pavement surface condition rating shown below. (If there is an unpaved shoulder, PC_l should be left blank. See roadside profile condition.)

Pavement Condition Descriptions

RATING	PAVEMENT CONDITION
5.0 (Very Good)	Only new or nearly new pavements are likely to be smooth enough and free of cracks and patches to qualify for this category.
4.0 (Good)	Pavement, although not as smooth as described above, gives a first class ride and exhibits signs of surface deterioration.
3.0 (Fair)	Riding qualities are noticeably inferior to those above; may be barely tolerable for high-speed traffic. Defects may include rutting, map cracking, and extensive patching.
2.0 (Poor)	Pavements have deteriorated to such an extent that they affect the speed of free-flow traffic. Flexible pavement has distress over 50 percent or more of the surface. Rigid pavement distress includes joint spalling, patching, etc.
1.0 (Very Poor)	Pavements that are in an extremely deteriorated condition. Distress occurs over 75 percent or more of the surface.

Source: U.S. Department of Transportation. Highway Performance Monitoring System-Field Manual. Federal Highway Administration. Washington, DC 1987.

% Occupied On-Street Parking - This is an estimate on the percentage of the segment (excluding driveways) along which there is occupied on-street parking at the time of survey. Each side is measured in increments of 25% and is recorded separately: "N/E" is the North or East side of the road and "S/W" is the South or West side of the road. **If the parking is allowed only during off-peak periods, this should be indicated in the comments field (this is typically indicated by a parking restriction sign).** Angled parking is also reported in the comments field.



Curb – “Y” is recorded if there is a curb on the segment. “N” is entered if there is an open shoulder.

Gutter Pan – “Y” indicates that the segment has a gutter pan (usually concrete, but can be brick); otherwise “N” is entered.

Designated Bike Lane - “Y” indicates that a bike lane is designated (by sign or pavement markings) on the segment, otherwise “N” is entered.

Designated Bicycle Route – “Y” indicates that the segment is marked with bicycle route (segment has green “BIKE ROUTE” signs or signs with a specific bike route letter or number), otherwise “N” is entered.

Share the Road Signs – “Y” indicates that the segment is marked with “Share the Road” signs (yellow bike warning sign with “Share the Road” beneath), otherwise “N” is entered.

Rumble Strips – “Y” indicates that the segment has shoulder rumble strips, otherwise “N” is entered. Note the approximate width of the rumble strips in the comments field and whether they are on the shoulder or travel lane.

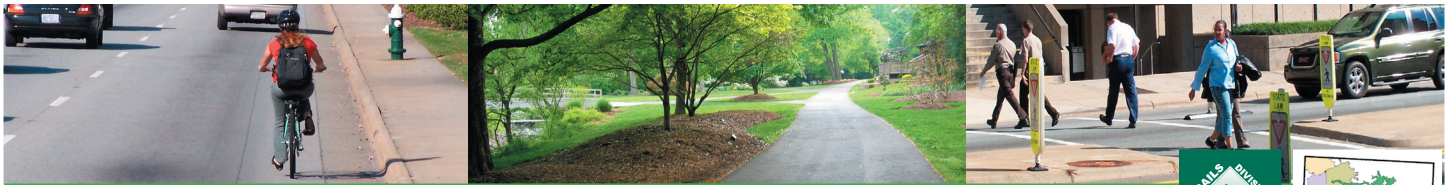
Steep Grade – “Y” indicates that the segment has a steep grade. A steep grade is considered to be a grade of over 8%, as estimated by the data collection team.

% of Segment with Sidewalk or Sidepath - The percentage of sidewalk coverage (estimated in increments of 10%) of the segment is to be collected for both sides of the roadway. Sidepaths and trails within the roadway right-of-way should be considered to be sidewalks for the purpose of data collection. Make sure to collect information about sidewalks on bridges. Each side is measured in increments of 10% and is recorded separately: “N/E” is the North or East side of the road and “S/W” is the South or West side of the road.

Buffer Width (W_b) - The width of a grass or other buffer between the edge of the pavement (or curb face, which includes the top of the curb, if present) and the beginning edge of the sidewalk. If the sidewalk contains a line of trees, mailboxes, plantings, etc., the width of these obstructions should be included in the buffer width measurement. The gutter pan is not included in the buffer. If the buffer is different on each side of the road, the average width is recorded.

Tree Spacing in Buffer - The spacing of trees within a buffer measured from foot on center (length of spacing between trees). Trees can either be in a grass buffer or in a sidewalk. Trees that are not between the sidewalk and roadway should not be considered. If the tree spacing is different on each side of the road, the average spacing is recorded.

Sidewalk/Sidepath Width (W_s) - The width of the sidewalk (or sidepath), measured from the edge of the buffer to the backside of the sidewalk. If a grass buffer is not present, the width is measured from the curb face (the top of the curb is included in the measurement). Each side is measured separately: “N/E” is the North or East side of the road and “S/W” is the South or West side of the road.



Roadside Profile Condition – This data item will be used to assist in determining the condition of the lateral area available for bikeway, sidepath or sidewalk construction. This evaluation is meant to be general, and is applied to area between the outside edge of the pavement and the right-of-way line, or the 10-20 feet of space adjacent to the edge of the pavement. Roadside profiles will be rated 1, 2, or 3. Condition 1 represents generally good conditions for building a shoulder, sidewalk, or sidepath, such as a built gravel shoulder of 4'+ or 10-12 feet of clear space, free of obstructions and with a grade similar to the roadway. Condition 2 represents a somewhat buildable shoulder which may be narrower, have more frequent obstructions or some areas with steeper grades. Condition 3 represents roadside conditions with severe slopes, ditches, trees or other features making it unbuildable without a major construction effort. **If the Roadside Profile Condition is 1 or 2, you may make a general assessment of the type of facility that could be constructed (see final two data collection items, below).**

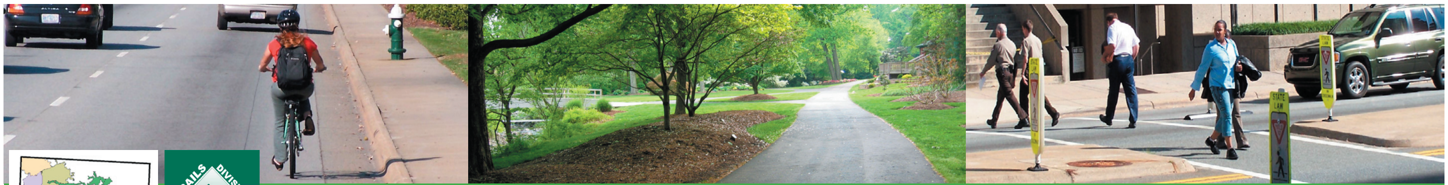
Potential Shoulder – "Y" indicates that a paved shoulder could be added to the segment without significant landscaping or reconstruction work; "N" suggests that adding a paved shoulder would require modification of the roadway or adjacent properties (such as filling ditches/regrading the land adjacent to the roadway, narrowing the roadway, moving utility poles, cutting down trees, razing buildings, etc.).

Potential Sidewalk/Sidepath – "Y" indicates that a sidewalk/sidepath could be added to the segment without significant landscaping or reconstruction work; "N" suggests that adding a sidewalk/sidepath would require modification of the roadway or adjacent properties (such as filling ditches/regrading the land adjacent to the roadway, narrowing the roadway, moving utility poles, cutting down trees, razing buildings, etc.).

Notes:

The accuracy of all width measurements is 0.5 feet. Measurements should be taken from the middle of roadway stripes (or the middle between the two centerline stripes). When there is a major change in roadway cross-section within a segment (i.e. the road changes from 2 lanes to 4 lanes in the middle of the segment), the two parts of the segment should be entered on two separate lines on the data collection sheet. Minor changes, such as changes in speed limit, several feet of variation in paved shoulder width, or narrowing of lanes at a small bridge do not require resegmentation. **In these cases, the predominant cross-section characteristics should be recorded and notes regarding variations should be recorded in the comments field.** In addition, if there is any noticeable difference in the above parameters between two directions (north/south or east/west) on a roadway segment, the data describing the other direction should be recorded in the comment field of the database, along with the direction. All other special conditions and assumptions made during the data collection on the segments should be recorded in the comments field of the database.

Please call Bob Schneider at Toole Design Group (301-927-1900 x107) if you have any questions while collecting data in the field.



E.2 Bicycle Level of Service Model Summary

Background

Level of Service (LOS) is a framework that transportation professionals use to describe existing conditions (or suitability) for a mode of travel in a transportation system. The traffic planning and engineering discipline has used LOS models for motor vehicles for several decades. Motor vehicle LOS is based on average speed and travel time for motorists traveling in a particular roadway corridor. In the 1990s, new thinking and research contributed to the development of methodologies for assessing levels of service for other travel modes, including bicycling, walking, and transit. Specific methodologies for bicycle level of service have been developed and used by a number of cities, counties, and states around the U.S. since the mid-1990s. This Plan adopts the Bicycle Level of Service (Bicycle LOS) Model assessment method.

When considering level of service in a multi-modal context, it is important to note that LOS measures for motor vehicles and bicycles are based on different criteria and are calculated on different inputs. Motor vehicle LOS is primarily a measure of speed, travel time, and intersection delay. Bicycle LOS is a more complex calculation, which represents the level of comfort a bicyclist experiences in relation to motor vehicle traffic.

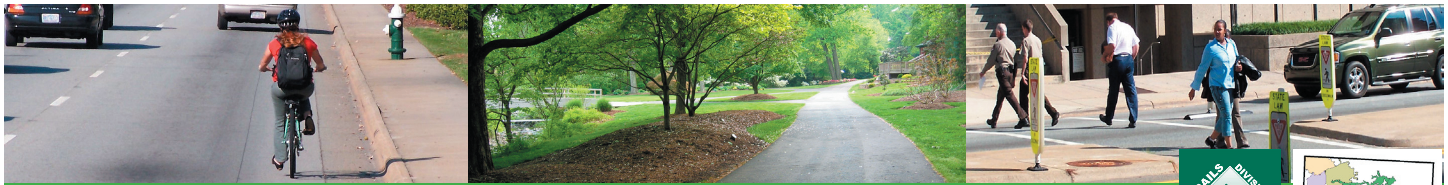
Bicycle Level of Service Model

The *Bicycle Level of Service Model (Bicycle LOS Model)* is an evaluation of bicyclist perceived safety and comfort with respect to motor vehicle traffic while traveling in a roadway corridor. It identifies the quality of service for bicyclists or pedestrians that currently exists within the roadway environment.

The statistically calibrated mathematical equation entitled the *Bicycle LOS Model*[1] *(Version 2.0)* is used for the evaluation of bicycling conditions in shared roadway environments. It uses the same measurable traffic and roadway factors that transportation planners and engineers use for other travel modes. With statistical precision, the *Model* clearly reflects the effect on bicycling suitability or "compatibility" due to factors such as roadway width, bike lane widths and striping combinations, traffic volume, pavement surface condition, motor vehicle speed and type, and on-street parking.

The *Bicycle Level of Service Model* is based on the proven research documented in *Transportation Research Record 1578* published by the Transportation Research Board of the National Academy of Sciences. It was developed with a background of over 150,000 miles of evaluated urban, suburban, and rural roads and streets across North America. Many urban planning agencies and state highway departments are using this established method of evaluating their roadway networks. The Virginia Department of Transportation is using the *Bicycle LOS Model* in both the Richmond and Northern Virginia regions. The model has also been applied in Anchorage AK, Baltimore MD, Birmingham AL, Buffalo NY, Gainesville FL, Houston TX, Lexington KY, Philadelphia PA, Sacramento CA, Springfield MA, Tampa FL, Washington, DC, Winston-Salem, NC, and by the Delaware Department of Transportation (DelDOT), Florida Department of Transportation (FDOT), New York State Department of Transportation (NYDOT), Maryland Department of Transportation (MDOT) and many others.

Widespread application of the original form of the *Bicycle LOS Model* has provided several refinements. Application of the *Bicycle LOS Model* in the metropolitan area of Philadelphia resulted in the final definition of the three effective width cases for evaluating roadways with on-street parking. Application of the *Bicycle LOS Model* in the rural



areas surrounding the greater Buffalo region resulted in refinements to the "low traffic volume roadway width adjustment." A 1997 statistical enhancement to the *Model* (during statewide application in Delaware) resulted in better quantification of the effects of high speed truck traffic [see the $SP_t(1+10.38HV)^2$ term]. As a result, *Version 2.0* has the highest correlation coefficient ($R^2 = 0.77$) of any form of the *Bicycle LOS Model*.

Version 2.0 of the *Bicycle Level of Service Model (Bicycle LOS Model)* will be employed to evaluate collector and arterial roadways in the Greensboro Metropolitan Area. Its form is shown below:

Bicycle LOS = $a_1 \ln (Vol_{15}/L_n) + a_2 SP_t(1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4(W_e)^2 + C$

Where:
Vol_{15}=Volume of directional traffic in 15 minute time period

$Vol_{15} = (ADT \times D \times K_d) / (4 \times PHF)$

where:
ADT = Average Daily Traffic on the segment or link
D = Directional Factor (assumed = 0.565)
K_d = Peak to Daily Factor (assumed = 0.1)
PHF = Peak Hour Factor (assumed = 1.0)

L_n = Total number of directional *through* lanes
SP_t = Effective speed limit

$SP_t = 1.1199 \ln(SP_p - 20) + 0.8103$

where:
SP_p = Posted speed limit (a surrogate for average running speed)

HV = percentage of heavy vehicles (as defined in the 1994 Highway Capacity Manual)
PR_5 = FHWA's five point pavement surface condition rating

W_e = Average effective width of outside through lane:

where:
$W_e = W_v - (10 \text{ ft} \times \% \text{ OSPA})$
and $W_l = 0$
$W_e = W_v + W_l(1 - 2 \times \% \text{ OSPA})$
and $W_l > 0$ & $W_{ps} = 0$
$W_e = W_v + W_l - 2(10 \times \% \text{ OSPA})$
and $W_l > 0$ & $W_{ps} > 0$
and a bikelane exists

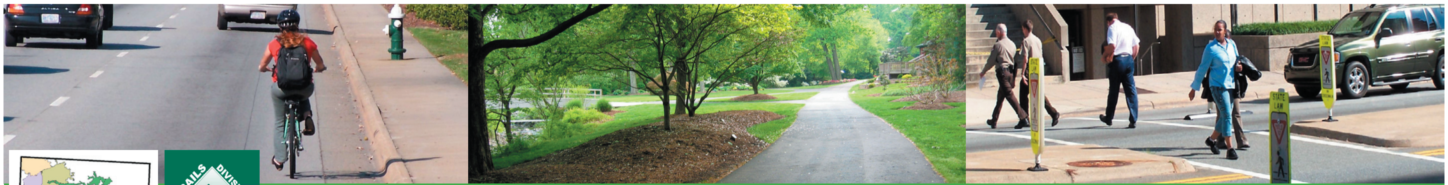
where:
W_t = total width of outside lane (and shoulder) pavement
OSPA = percentage of segment with occupied on-street parking
W_l = width of paving between the outside lane stripe and the edge of pavement
W_{ps} = width of pavement striped for on-street parking
W_v = Effective width as a function of traffic volume

and:

$W_v = W_t$
if ADT > 4,000veh/day
$W_v = W_t(2-0.00025 \times ADT)$
if ADT ≤ 4,000veh/day
and if the street/ road is undivided and unstriped

a_1: 0.507 a_2: 0.199 a_3: 7.066 a_4: - 0.005 C: 0.760

(a_1 - a_4) are coefficients established by the multi-variate regression analysis.



The Bicycle LOS score resulting from the final equation is pre-stratified into service categories "A", "B", "C", "D", "E", and F" ("A" is best, and "F" is worst), according to the ranges shown in Table 1, reflecting users' perception of the road segments level of service for bicycle travel. This stratification is in accordance with the linear scale established during the referenced research (i.e., the research project bicycle participants' aggregate response to roadway and traffic stimuli). The *Model* is particularly responsive to the factors that are statistically significant. An example of its sensitivity to various roadway and traffic conditions is shown on the following page.

Because the model represents the comfort level of a hypothetical "typical" bicyclist, there are some bicyclists who may feel more comfortable and others who may feel less comfortable than the Bicycle Level of Service calculated for a roadway. A poor Bicycle Level of Service grade does not mean that bikes should be prohibited on a roadway.

Bicycle Level-of-Service Categories

LEVEL-OF-SERVICE	Bicycle LOS Score
A	≤ 1.5
B	> 1.5 and ≤ 2.5
C	> 2.5 and ≤ 3.5
D	> 3.5 and ≤ 4.5
E	> 4.5 and ≤ 5.5
F	> 5.5

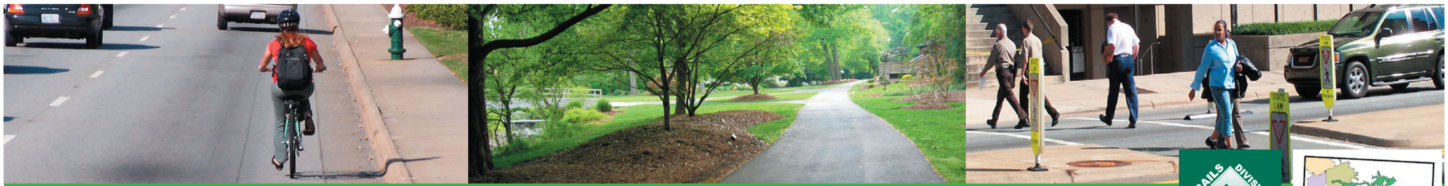
The Model represents the comfort level of a hypothetical "typical" bicyclist. Some bicyclists may feel more comfortable and others may feel less comfortable than the Bicycle LOS grade for a roadway. A poor Bicycle LOS grade does not mean that bikes should be prohibited on a roadway.

It suggests to a transportation planner that the road may need other improvements (in addition to shoulders) to help more bicyclists feel comfortable using the corridor.

Application

The *Bicycle LOS Model* is used by planners, engineers, and designers throughout the US and Canada in a variety of planning and design applications. Applications include:

1) Conducting a benefits comparison among proposed bikeway/roadway cross-sections
2) Identifying roadway restriping or reconfiguration opportunities to improve bicycling conditions
3) Prioritizing and programming roadway corridors for bicycle improvements
4) Creating bicycle suitability maps
5) Documenting improvements in corridor or system-wide bicycling conditions over time



Bicycle LOS Model Sensitivity Analysis

Bicycle LOS = $a_1 \ln(Vol_{15}/Ln) + a_2 SP_t(1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4 (W_e)^2 + C$

where: a_1: 0.507 a_2: 0.199 a_3: 7.066 a_4: -0.005 C: 0.760
T-statistics: a_1: (5.689) a_2:(3.844) a_3: (4.902) a_4: (-9.844)

Baseline inputs:

ADT = 12,000 vpd % HV = 1 L = 2 lanes
SP_p = 40 mph W_e = 12 ft PR_5 = 4 (good pavement)

	BLOS	% Change
Baseline BLOS Score (Bicycle LOS)	3.98	N/A

Lane Width and Lane striping changes

W_t	=	10 ft	4.20	6% increase
W_t	=	11 ft	4.09	3% increase
W_t	=	12 ft - - (baseline average) - - - - - - -	3.98 - - - -	no change
W_t	=	13 ft	3.85	3% reduction
W_t	=	14 ft	3.72	7% reduction
W_t	=	15 ft (W_l = 3 ft)	3.57 (3.08)	10%(23%) reduction
W_t	=	16 ft (W_l = 4 ft)	3.42 (2.70)	14%(32%) reduction
W_t	=	17 ft (W_l = 5 ft)	3.25 (2.28)	18%(43%) reduction

Traffic Volume (ADT) variations

ADT	=	1,000 Very Low	2.75	31% decrease
ADT	=	5,000 Low	3.54	11% decrease
ADT	=	12,000 Average - (baseline average) - -	3.98 - - - - -	no change
ADT	=	15,000 High	4.09	3% increase
ADT	=	25,000 Very High	4.35	9% increase

Pavement Surface conditions

PR_5	=	2 Poor	5.30	33% increase
PR_5	=	3 Fair	4.32	9% reduction
PR_5	=	4 - - Good - (baseline average) - - -	3.98 - - - -	no change
PR_5	=	5 Very Good	3.82	4% reduction

Heavy Vehicles in percentages

HV	=	0 No Volume	3.80	5% decrease
HV	=	1 - - - Very Low - (baseline average) - -	3.98 - - - - - -	no change
HV	=	2 Low	4.18	5% increase
HV	=	5 Moderate	4.88	23% increase$_a$
HV	=	10 High	6.42	61% increase$_a$
HV	=	15 Very High	8.39	111% increase$_a$

$_a$Outside the variable's range (see Reference *(1)*)



(Endnotes)

[1]Landis, Bruce W. et.al. "Real-Time Human Perceptions: Toward a Bicycle Level of Service" *Transportation Research Record 1578*, Transportation Research Board, Washington, DC 1997.